NASA CR-156874

S...

GENERAL DESCRIPTION AND OPERATION OF THE AGRO-ENVIRONMENTAL SYSTEM

CROP MANAGEMENT MODELING

Virginia Polytechnic Institute and State University
Blacksburg, VA

and

National Aeronautics and Space Administration
Wallops Flight Center, Wallops Island, VA

GENERAL DESCRIPTION

AND

OPERATION

OF THE

AGRO-ENVIRONMENTAL SYSTEM

CROP MANAGEMENT MODELING

Virginia Polytechnic Institute and State University
Blacksburg, VA

and

National Aeronautics and Space Administration
Wallops Flight Center, Wallops Island, VA

TABLE OF CONTENTS

PREFACE

The art of agricultural crop modeling is not a new science, however, the manipulation of the huge amounts of environmental data required to implement such models has previously presented a technically impractical and time consuming task. The advent of computer technology, especially in the field of component miniaturization, has now made it possible and practical to reduce the time required to accomplish crop modeling to a fantastically short time period. Hence the science of agricultural crop management modeling has become a realistic and valuable tool that may now be exploited by the industry.

Utilization of this tool will rely heavily on research that must be completed before the results can be provided for public consumption and benefit. Such research involves the collection of essential environmental data from a large area monitoring system. This manual is an attempt to describe a core system that has been constructed in the state of Virginia for this purpose.

It is a highly flexible system that can be easily adapted to a variety of conditions at the convenience of designers of new research programs. Continued expansion is anticipated as the system attempts to meet the expected heavy demands of the agricultural industry in the future. If such usage is to be fully implemented, it is essential that the core system be documented to provide present and future users with the proper information related to development, design, and operation. Therefore, this documentation is offered as an aid to those personnel interested in the Agro-Environmental Monitoring System and its future usage.

A. INTRODUCTION

The relationship of man to his environment is a constant source of study to scientists interested in man's survival within that environment.

This study becomes one of reverent fascination as long as natural environmental forces are undisturbed by man's habitation. The same study becomes one of alarm when some environmental perturbation is injected into an otherwise balanced environment. When this balance is preserved the food supply is bountiful, and life is bearable; but when it is upset by uncooperative weather, insects, or diseases even man's existence can become endangered.

For some time man has been able to maintain at least some control of this balance by arming himself with irrigation to cope with drought conditions and chemicals with which to diminish or control insects and diseases of his crops. But the use of chemicals, sometimes to excess, has created another problem - pollution of the environment.

This situation emphasizes the delicate nature of this environmental balance and points out man's dependency. Environmental data provides the common denominator upon which the scientist bases his analysis of these imbalances. He relates his findings directly to various combinations of these environmental factors.

Agriculture as an industry is composed of many complex, interrelated systems controlled by weather, one of the most important variables faced by farmers. Understanding the weather and its effect on these systems creates possibilities for breakthroughs in control of pests and improvement of the efficiency of agricultural production.

Farmers spend $7 billion a year for pesticides and $10.5 billion for herbicides. Researchers estimate that a fully implemented agricultural weather program combined with integrated pest management could result in reducing the amount of pesticides by 20 percent. They also estimate that 25 percent of the herbicides applied by American farmers are ineffective because of incorrect scheduling of application in relation to existing weather conditions. Irrigation is a critical component in the nation's agricultural industry, and research indicates that the efficiency of supplemental irrigation can be improved by proper use of weather data during irrigation scheduling.

Virginia scientists and agriculturalists are confident that if specific environmental factors of agricultural importance are constantly monitored that it will be possible to determine with more accuracy the types and amounts of chemicals and water to apply to certain crops. Planting and harvesting dates can also be determined in this same manner.

B. BACKGROUND

In 1974 Dr. David E. Pettry, professor of agronomy, Virginia Polytechnic Institute and State University (Virginia Tech), proposed the development of a data management system which would provide farmers with information to improve their crop management practices. (Dr. Pettry was later employed by Mississippi State University and was succeeded by Dr. Norris L. Powell).

A primary function of the Applications Office, National Aeronautics and Space Administration (NASA), is to transfer space derived technology to the user community. To accomplish this end NASA responded to the proposal from Virginia Tech by funding a joint effort to initiate such a project. An agreement was signed in 1974, a Research Technology Operating Plan was submitted, and work commenced on the Agro-Environmental Monitoring System (AEMS).

The general concept involved the collection of a large base of environmental data from selected sites throughout the state of Virginia. This data would then be transmitted to a centralized computer which would process the information for input into a mathematical model that would assist agriculturalists in determination of solutions to crop management problems. Conceptually, the system would be agriculturally oriented, but the data and the system would be available to all other disciplines for application to such problems as flood control, pollution, erosion, energy, etc.

Under the agreement, the NASA Wallops Flight Center at Wallops Island, Virginia, provided the funding, the overall systems engineering expertise, and the technical capability required to identify and design the specific hardware to make up the data collection system. Virginia Tech supplied the scientific capability needed to identify the environmental and agronomic problems and the expertise to develop the crop management models.

During the development stage, NASA provided funding for the project.

$50,000 was supplied by the Virginia Department of Agriculture and Consumer Services, and the Virginia state legislature appropriated $110,000 for each year of the 1980-1982 biennium. Virginia Tech supplied the project staff and the needed physical facilities.

Also during the formative years, the project solicited the aid of an Advisory Group composed of personnel from Virginia Tech, NASA, other federal and state agencies, and agriculturalists. Members included:

S. Mason Carbaugh, Commissioner, Virginia Department of Agriculture and Consumer Services.

Dr. Richard E. Felch, National Weather Service, NOAA.

R. M. Hardy, Virginia Soil and Water Conservation Commission.

Dr. A. J. Loustalot, CSRS, U. S. Department of Agriculture.

W. H. Matheny, State Entomologist, Virginia Department of Agriculture and Consumer Services.

Dr. Robert H. Miller, ARS, U. S. Department of Agriculture.

Dr. James L. Tramel, Director, Southern Piedmont Research and Continuing Education Center.

Dr. Frederick P. Weber, Forest Service, U. S. Department of Agriculture.

Donald L. Wells, Virginia Soil and Water Conservation Commission.

Dr. Coyt T. Wilson, Director, Virginia Agricultural Experiment Stations.

C. THE PROJECT

The prime objectives of the project were to:

1. Develop and install a data collection system to measure the environmental parameters affecting crop growth and conditions.
2. Provide critical environmental information for agriculturalists to manage their operations and increase the economic returns from crops.
3. Provide standard environmental data for researchers to develop improved crop production practices.
4. Provide ground truth information for operational satellite systems and other remote sensing projects.

The Agro-Environmental Monitoring System (AEMS) is designed to handle the acquisition, processing, and storage of data so that it can be easily retrieved. Sufficient flexibility is also designed into the system to permit the expansion and addition of new data sources. Development has progressed to the point where information from the system is now being used to develop crop management models.

The first of these models, the Cercospora Leafspot model, will be ready for on-line operation in 1981. This model has been evaluated by extensive field testing during the past three growing seasons. Test plots were selected on six peanut farms during 1979. Each of these plots was divided into three equal parts - one controlled by the model, one controlled by the conventional spray schedule, and one uncontrolled. Similar testing was conducted during 1980. All testing prior to 1979 was accomplished by use of historical data.

Several crop management models are under development, and others are planned; Cylindtocladium Blackrot and Sclerotinia blight of peanuts, cyst nematode (Globerdena solanacearum) of tobacco, and red crown rot of soybeans, all of which cause considerable economic loss to Virginia farmers. In addition to these models a software program is being developed to estimate precipitation and solar radiation on a statewide basis.

During the development and evaluation phase a large number of scientists and agriculturalists have become involved with crop modeling as a means of enhancing crop management practices. Their evaluation of the system includes determination of cost benefits by comparing labor and chemical costs and yields produced under conventional techniques with those produced under model controlled conditions.

This same group of researchers will share the responsibility of providing new models and expanding the system. The extension service will be expected to provide the information network needed to disseminate crop advisories to individual growers on a daily basis. Administration, operation, and maintenance of the system becomes the major responsibility of Virginia Tech.

D. THE SYSTEM

The AEMS consists of six unattended remote monitoring stations (two additional stations are to be added in the future), a central control station located at Virginia Tech, and computer access to several sources of support data (Figure 1).

Information obtained every 10 minutes at the field stations is stored in an on-site microprocessor which is interrogated once each day. During this interrogation the data is transferred to the minicomputer at the central control station where it is processed and archived. The archived data is available upon request to Virginia Tech by individuals or agencies who have a need for it. The central control station also stores and retrieves historical data from other sources.

The crop management models are actually run on the University computer in the computing center at Virginia Tech. In addition to the data from the central control station, inputs to the models include data from a precipitation and solar radiation estimation program. This program is developed from satellite data from the National Meteorological Center (NMC) and additional data from the Nationwide Agricultural Touchtone System (NATS). The later system consists of about 40 weather stations in and near Virginia and 150 volunteers (when fully operational) throughout the state.

D. 1. The Field Stations

The field stations are situated at agricultural experiment stations throughout the state of Virginia (Figure 2). They are so located to obtain complete coverage of environmental conditions within the state and to provide a means of security for the expensive hardware involved. Additionally, since certain environmental parameters cannot be automatically sensed, the on-site research scientists and technicians can manually input this important data into the system. The locations of these field monitoring units are:

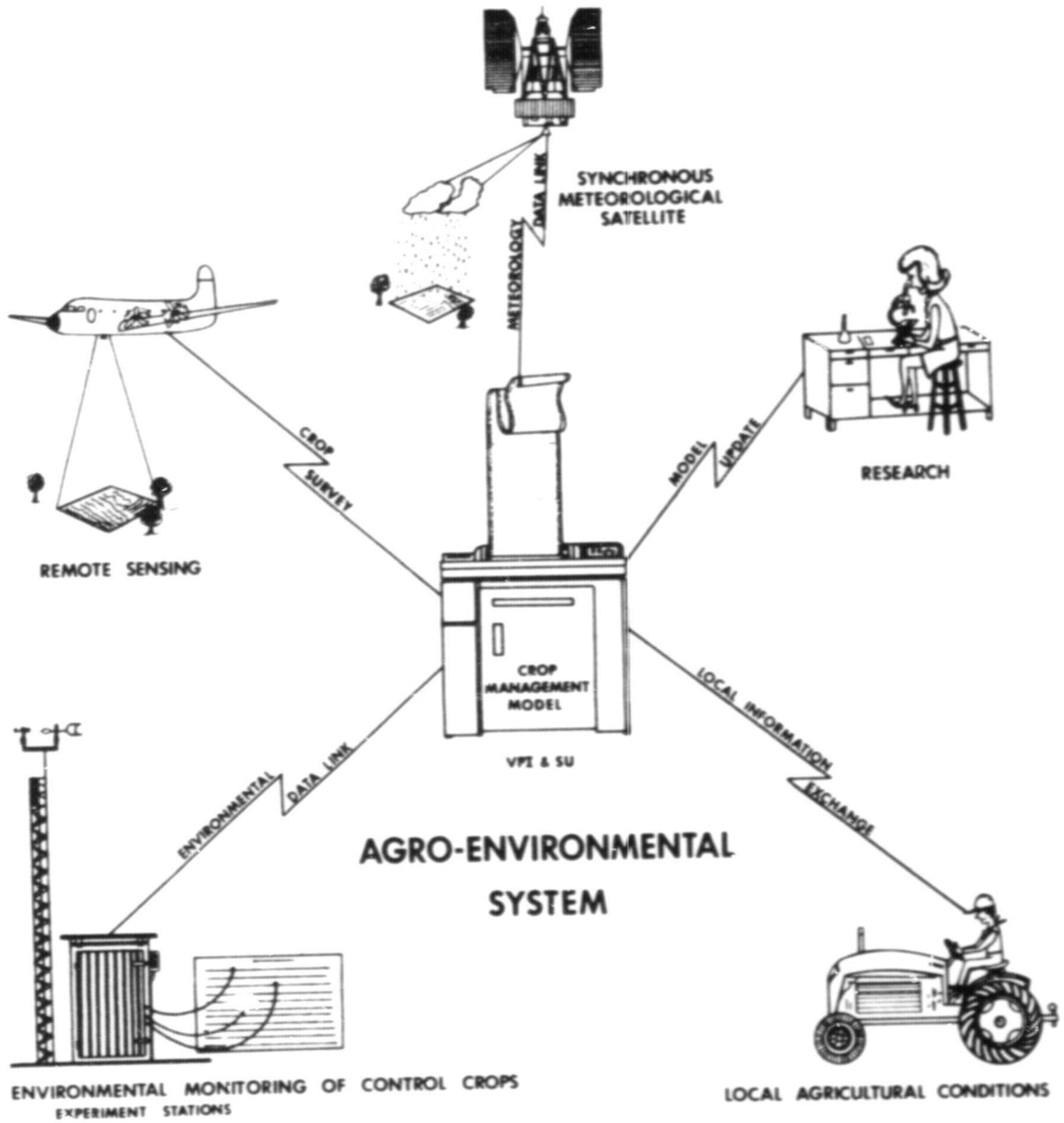

SYNCHRONOUS METEOROLOGICAL SATELLITE
DATA LINK
METEOROLOGY
REMOTE SENSING
CROP SURVEY
MODEL UPDATE
RESEARCH
CROP MANAGEMENT MODEL
VPI & SU
LOCAL INFORMATION EXCHANGE
ENVIRONMENTAL DATA LINK
AGRO-ENVIRONMENTAL SYSTEM
ENVIRONMENTAL MONITORING OF CONTROL CROPS
EXPERIMENT STATIONS
LOCAL AGRICULTURAL CONDITIONS

Figure 1

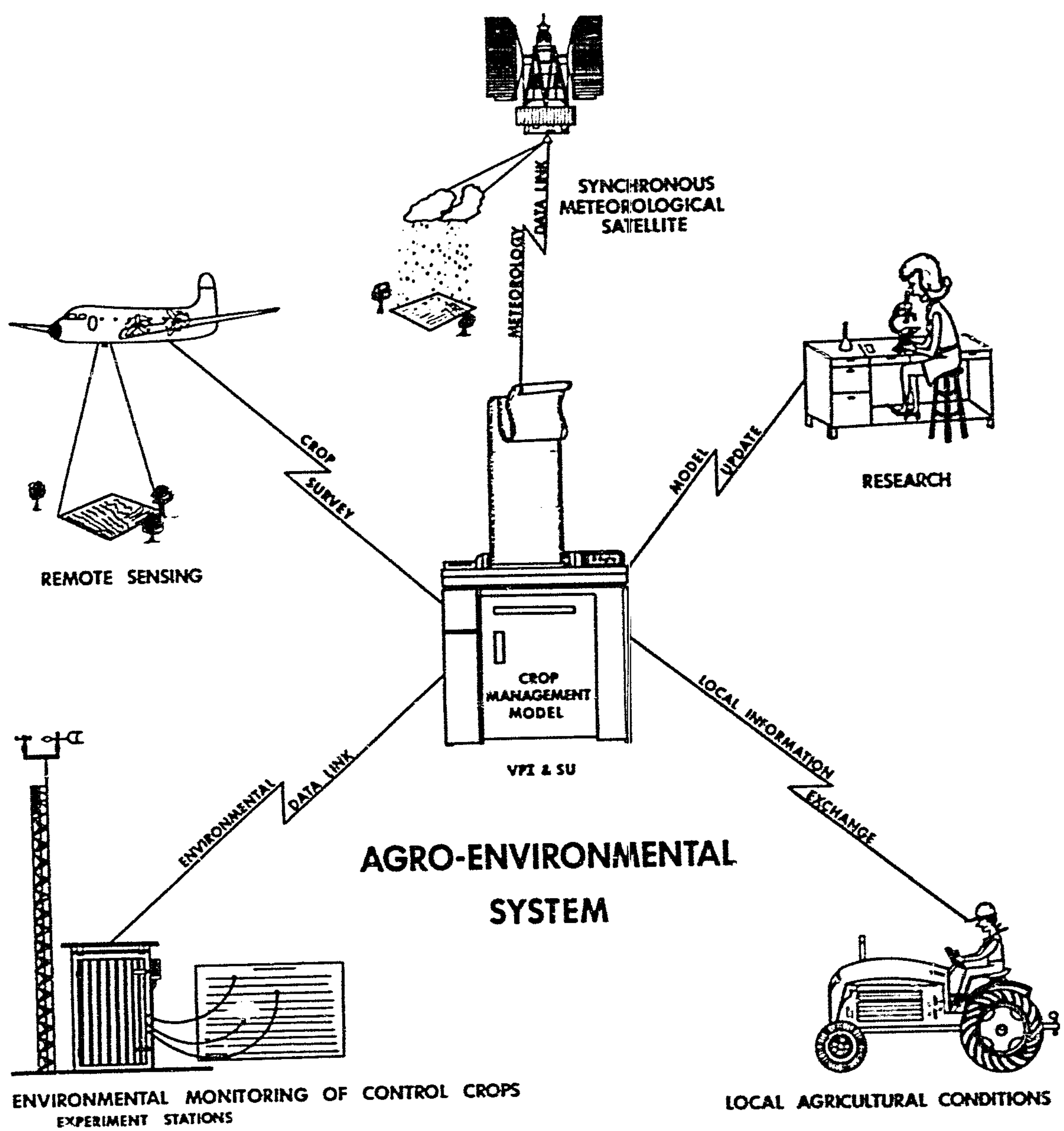
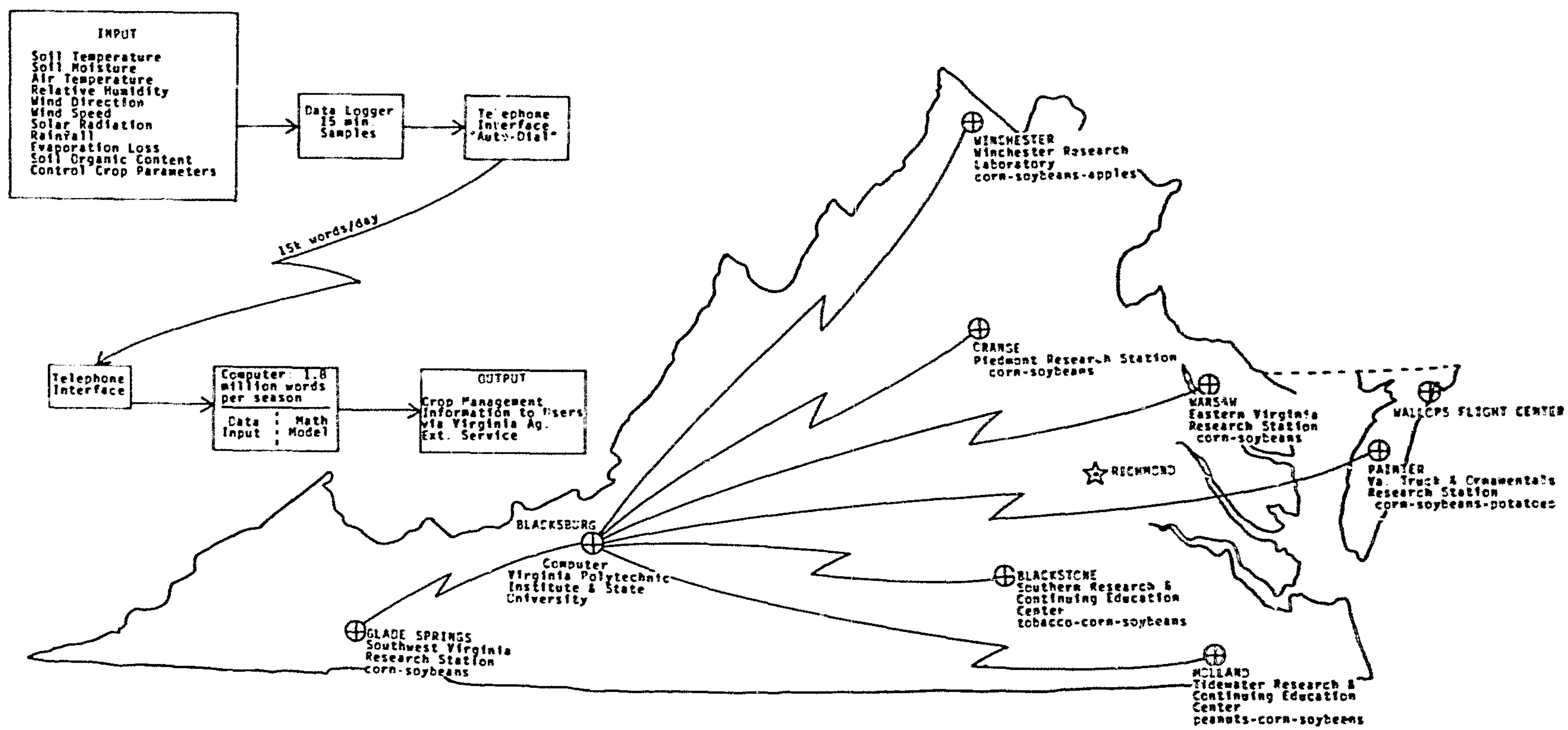

SYNCHRONOUS
METEOROLOGICAL
SATELLITE
DATA LINK
METEOROLOGY
CROP
SURVEY
REMOTE SENSING
MODEL
UPDATE
RESEARCH
CROP
MANAGEMENT
MODEL
VPI & SU
LOCAL INFORMATION
EXCHANGE
ENVIRONMENTAL
DATA LINK
AGRO-ENVIRONMENTAL
SYSTEM
ENVIRONMENTAL MONITORING OF CONTROL CROPS
EXPERIMENT STATIONS
LOCAL AGRICULTURAL CONDITIONS

Figure 1



AGRO-ENVIRONMENTAL SYSTEM

Figure 2

a. Tidewater Research and Continuing Education Center, Suffolk.

b. Southern Piedmont Research and Continuing Education Center, Blackstone.

c. Virginia Truck and Ornamentals Research Station, Painter.

d. Eastern Virginia Research Station, Warsaw.

e. Piedmont Research Station, Orange.

f. Virginia Tech Turfgrass Research Station, Blacksburg.

The two additional stations are planned for:

g. Southwest Virginia Research Station, Glade Spring.

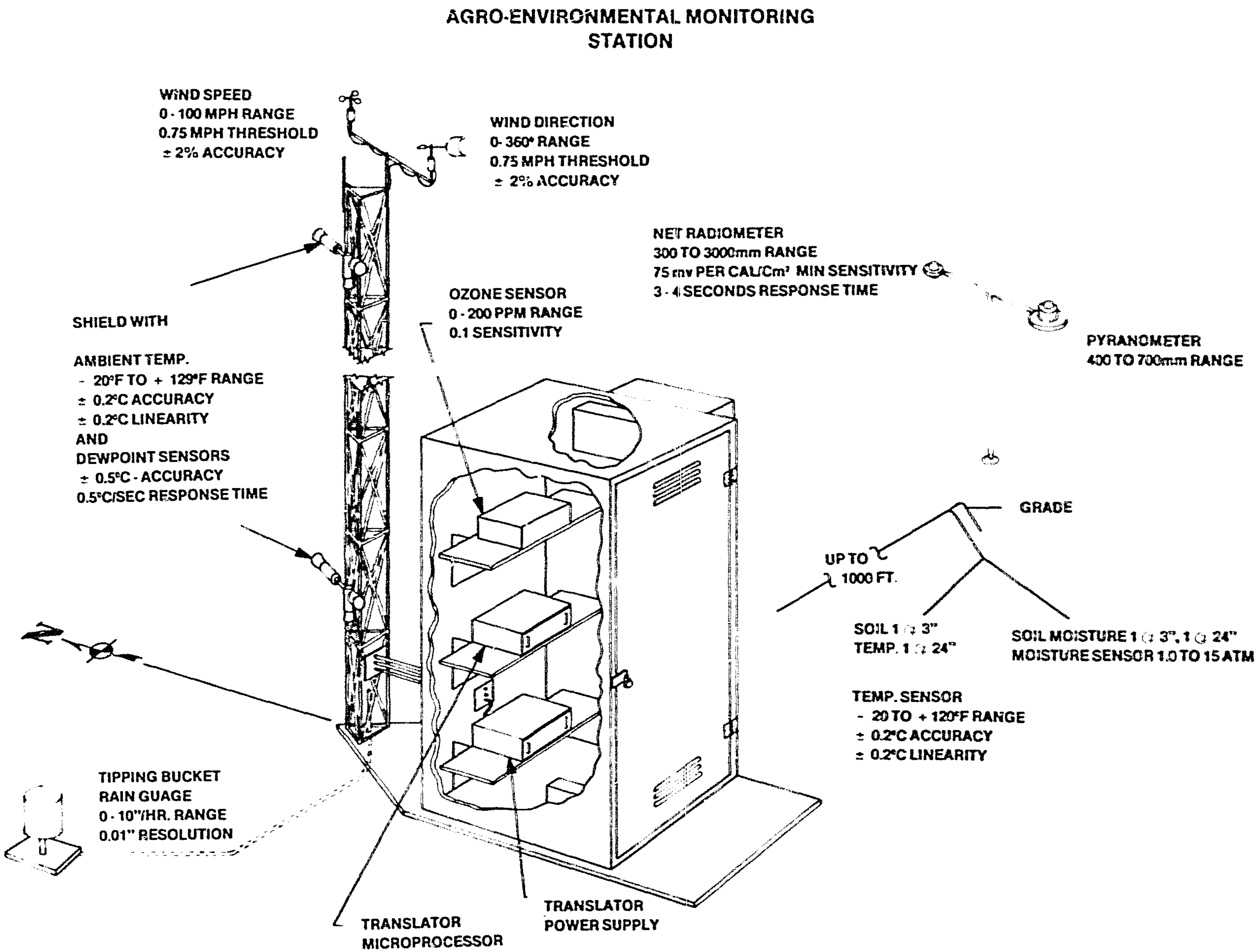
h. Winchester Fruit Research Laboratory, Winchester.

A wide variety of physical quantities of the environment can be observed and collected at these locations. All stations are equipped to measure wind speed, wind direction, solar radiation, photosynthetically active solar radiation, ambient air temperature, dew point, precipitation, soil temperature at several depths, barometric pressure, and leaf wetness. Measurements of ozone and SO_2 concentrations are taken at several of the sites. Currently, soil moisture information is derived from the gravimetric analysis which consists of a manual collection process where the soil sample is weighed, dried, and then reweighed. An automatic soil moisture sensor suitable for this application simply does not exist under present day technology, therefore necessitating this tedious method of data procurement. Several programs are currently being conducted to develop a sensor for this purpose, and it is anticipated that one may be available in the near future.

Certain other parameters cannot be automatically obtained, and on-site support of the automatic data collection is required. Therefore, each of the experiment stations has been provided a data terminal to facilitate direct entry of external data into the system. In addition to soil moisture, data that is available only by this method includes soil pH, leaf area index, cultivation practices, fertility levels, etc.

The electronic components of the field station are sheltered in an environmentally controlled 4 x 4 x 7 foot steel box that maintains the shelter temperature within a range compatible with optimum equipment operation (Figure 3). This shelter is mounted on a reinforced concrete base which also supports a 20 foot tower upon which the wind instrumentation is mounted. The solar radiation instruments are located on the roof of the shelter, and the other sensors are located at convenient crop level heights near the shelter.

The function of the microprocessor controlled electronics within the shelter is two fold: data collection and transmission to the central control station (Figures 4A and 4B). The front end of the electronics provides for the data collection by selecting each parameter to be read at any given instant. This signal that is received from the sensor is applied to an analog-to-digital converter where it



AGRO-ENVIRONMENTAL MONITORING STATION
WIND SPEED
0 - 100 MPH RANGE
0.75 MPH THRESHOLD
± 2% ACCURACY
WIND DIRECTION
0- 360° RANGE
0.75 MPH THRESHOLD
± 2% ACCURACY
NET RADIOMETER
300 TO 3000mm RANGE
75 mv PER CAL/Cm² MIN SENSITIVITY
3 - 4 SECONDS RESPONSE TIME
OZONE SENSOR
0 - 200 PPM RANGE
0.1 SENSITIVITY
PYRANOMETER
400 TO 700mm RANGE
SHIELD WITH
AMBIENT TEMP.
- 20°F TO + 129°F RANGE
± 0.2°C ACCURACY
± 0.2°C LINEARITY
AND
DEWPOINT SENSORS
± 0.5°C - ACCURACY
0.5°C/SEC RESPONSE TIME
GRADE
UP TO
1000 FT.
SOIL 1 @ 3"
TEMP. 1 @ 24"
SOIL MOISTURE 1 @ 3", 1 @ 24"
MOISTURE SENSOR 1.0 TO 15 ATM
TEMP. SENSOR
- 20 TO + 120°F RANGE
± 0.2°C ACCURACY
± 0.2°C LINEARITY
TIPPING BUCKET
RAIN GUAGE
0 - 10"/HR. RANGE
0.01" RESOLUTION
TRANSLATOR
MICROPROCESSOR
TRANSLATOR
POWER SUPPLY

Figure 3

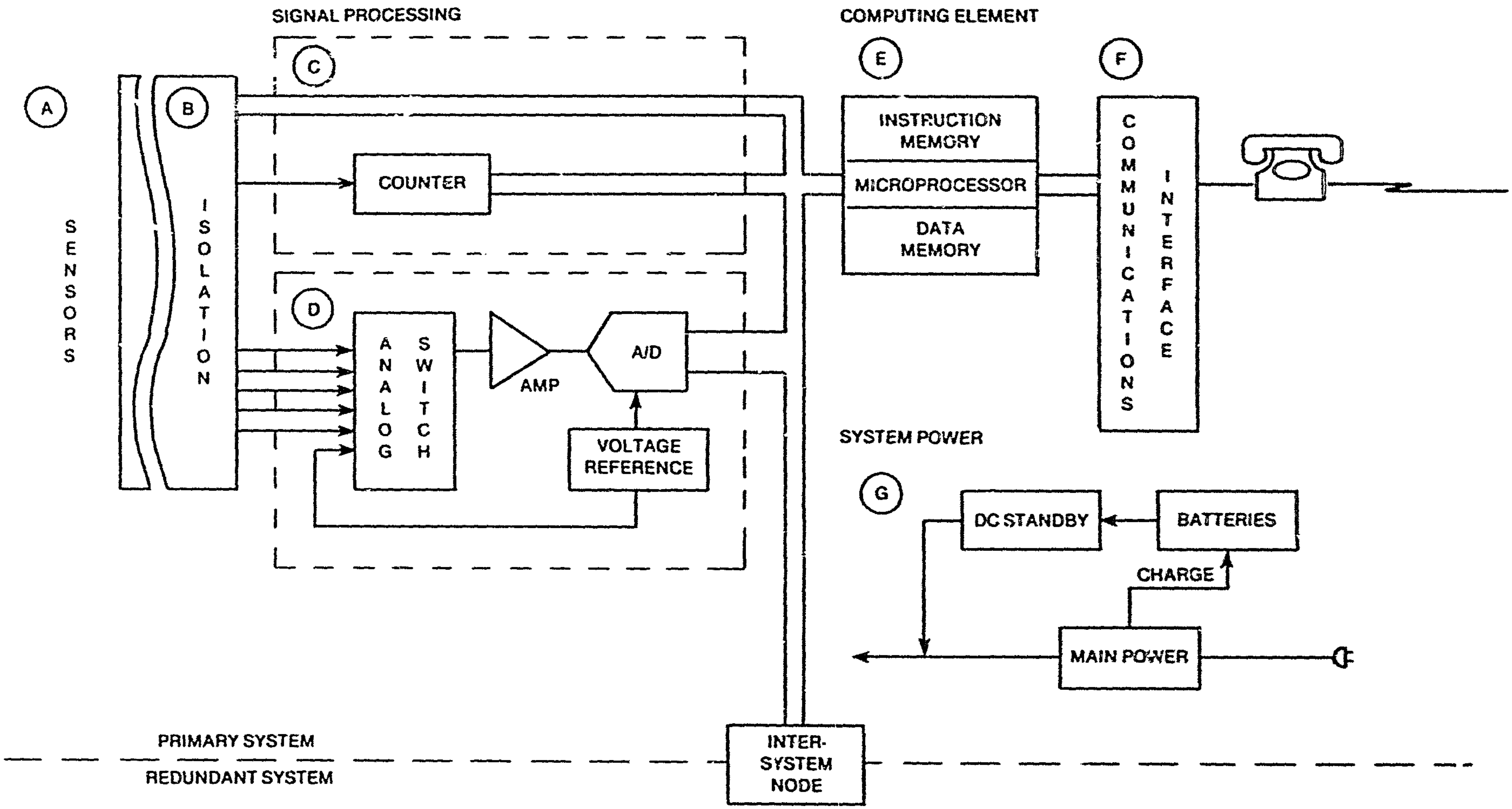

SIGNAL PROCESSING
COMPUTING ELEMENT
A
B
C
D
E
F
G
SENSORS
ISOLATION
COUNTER
ANALOG SWITCH
AMP
A/D
VOLTAGE REFERENCE
INSTRUCTION MEMORY
MICROPROCESSOR
DATA MEMORY
COMMUNICATIONS INTERFACE
SYSTEM POWER
DC STANDBY
BATTERIES
CHARGE
MAIN POWER
PRIMARY SYSTEM
REDUNDANT SYSTEM
INTER-SYSTEM NODE

Figure 4A

A. Sensors consist of wind speed; wind direction; precipitation; ambient temperature; dew point; soil temperature at 2, 4, and 18 inches; solar radiation; photosynthetic active radiation; leaf-wetness; and at two stations, atmospheric ozone concentration. Sensors selected primarily to provide environmental information to agriculture.

B. Isolation is necessary to prevent voltage and current transients generated during an electrical storm from temporarily destroying data or permanently damaging electronic components. Includes spark gaps, inductive and capacitative loading, high speed voltage clamps, and optical isolation.

C. Some data from digital signal sources (ozone monitor) are read directly by the system or converted from frequency domain with a counter (wind speed, precipitation). These signals usually at levels or format so that they can be stored directly as discrete numbers.

D. Continuously varying analog signals (current, voltage, resistance) are first converted or buffered by a signal conditioning amplifier to get proper voltage to be processed by an analog to digital converter, manipulated, and stored by the computing element. Current digital information created precisely represents the continuously varying output of a given sensor at a given time. Output of many sensors converted one at a time by means of a multiplexor (a solid state rotary switch) whose position is controlled by the microprocessor. Components have been so arranged that a high precision voltage reference is processed by a maximum number of elements through which the raw output of the sensors must pass. Being of a known value and being thus influenced by the same components, errors introduced by these components can be mathematically eliminated at the minicomputer. No calibration of the field data acquisition equipment is needed or provided.

E. The field station computing element consists of a microprocessor with a fixed program memory which instructs its operations and alterable read-write memory where data can be stored. Instructions have been encoded to take data from the signal processing element, file it into read-write memory, and subsequently deliver it to the minicomputer at Virginia Tech.

F. Communications interface translates data into signals that can be handled by a conventional telephone line. In addition, it automatically answers the phone, or will dial out if so requested, to establish a link with the central computing facilities.

G. A DC standby source was designed for this system to run in parallel with the main power source to prevent transients generated by conventional AC sources when switched in and out. It also overcomes the lack of reliability found in the uninterruptable power supplies (UPS's). A small AC standby unit is also used however to provide an alternate source of power to equipment using standard line current which is not susceptible to switching transients.

H. What has not been shown is the duplicate copy of the components above. Duplication provides total system redundancy so that no one component failure can result in loss of data.

Figure 4B

becomes a digital unit capable of manipulation and storage. These numbers are then accumulated into time-weighted averages that are filed every 10 minutes.

The remainder of the electronics handles the communications. When the station is interrogated it retrieves the information from the microprocessor, converts it into transmittable characters, and transmits it through a telephone connection to the central control station. Each 10 minute sample of information is contained in a single line of data which is checked by a redundant code to assure that it meets format requirements before responding to the data transmission routine. This procedure reduces the introduction of errors into the final record as well as reducing the loss of information. During the call precedence is given to communications over sensor sampling to keep telephone line costs to a minimum, occasionally resulting in the loss of one line of data.

Reliability and operational continuity were given high priority during the design stage of the project. In this respect, each station was designed with a backup system to avoid loss of data in the event of a malfunction of the primary control unit. The microprocessors are supported by an internal clock and a power system that automatically switches to a DC backup system should the AC power fail. In the event of a long term power failure, smoke alert, or memory overrun, the management unit can initiate its own call to the minicomputer at the central control station so that the data can be retained and remedial action taken quickly.

Maintaining the accuracy of data for mathematical models as it is being archived has also been given a high priority during the design stage. Reference signals derived from high precision components are acquired and processed along the same path and through the same signal conversion elements as the output from the sensors. Final extraction of corrected values and conversion into recognizable engineering units is delayed until the last possible moment. This integration of system tasks results in an overall reduction in the amount of components that have to be maintained, and it provides a straight and uncluttered path for the data until it is safely stored at the central control station.

Present planning includes expansion of the data handling capacity and refinement of the existing operations. At present, each microprocessor has a memory storage capacity of about 8,000 bytes or 2,000 data points, with a sensor input capability of 18 channels. In addition to adding memory, system expansion can be incorporated at three levels. Most of the stations have four unused channels available, and therefore require nothing more than sensor connection and software support. Thirty more channels can be added simply by installing six more signal conditioning cards. Finally, an almost unlimited number of channels can be accommodated by addition of new card cages. Discretion in limiting the resulting data base would probably restrict expansion long before the magnitude of field hardware and software reach a point of stress.

D. 2. The Central Control Station

The central control station at Virginia Tech (Figure 5) controls communications to all field stations - collecting and processing the data from these stations and other sources to provide the information needed by the mathematical crop management models. The central control station provides 64,000 bytes of memory storage and furnished tape, disc, or graphical output sources, allowing a considerable range of adaptability to external processing devices and routines.

At least once each day the central control station automatically dials each field station in sequence and interrogates its microprocessor. In response to the proper command the microprocessor transmits all of its data to the central station where it is tested to determine its integrity. This test includes comparison of the incoming data against certain reference data and calculation of correction factors as they are needed. Software is available to "red flag" the data if its integrity cannot be validated. At that point, a warning is issued demanding immediate reaction from operating personnel.

The raw data from the field stations (Figure 6) must be converted at the central control station into engineering units before being stored in the data base. During this part of the data handling process, possible sensor failures are detected and the erroneous data replaced with missing value designators before the converted data is stored. When a sensor failure is determined immediate action is taken to replace or repair it. The process of checking the integrity of the data will be greatly accelerated when a graphics terminal is installed permitting visual evaluation.

Information processing and storage events occur in the following sequence:

a. Raw field data arrives by telephone line connection at the central control station where it is placed in the minicomputer memory and simultaneously written onto a mass storage disc.

b. After the raw data is checked for inaccuracies or failures it is returned to the minicomputer to be stripped of overlapping material from the previous day and converted into engineering units (Figure 7), after which it is again stored on a disc.

c. The stripped raw data and the converted data are stored on a nine-track magnetic tape, providing information retrievability at any time in the future.

d. Processed data is then applied to the computer in Virginia Tech's computing center via a time sharing link for use in crop management models.

D. 3. Precipitation Estimation

A precipitation estimation program has been developed that provides rainfall estimates based on data obtained from GOES (Geostationary Operational Environmental Satellite) operated by the National Earth Satellite Service (NESS). Data obtained from infrared and visible imagery is received hourly from the satellite via a telephone

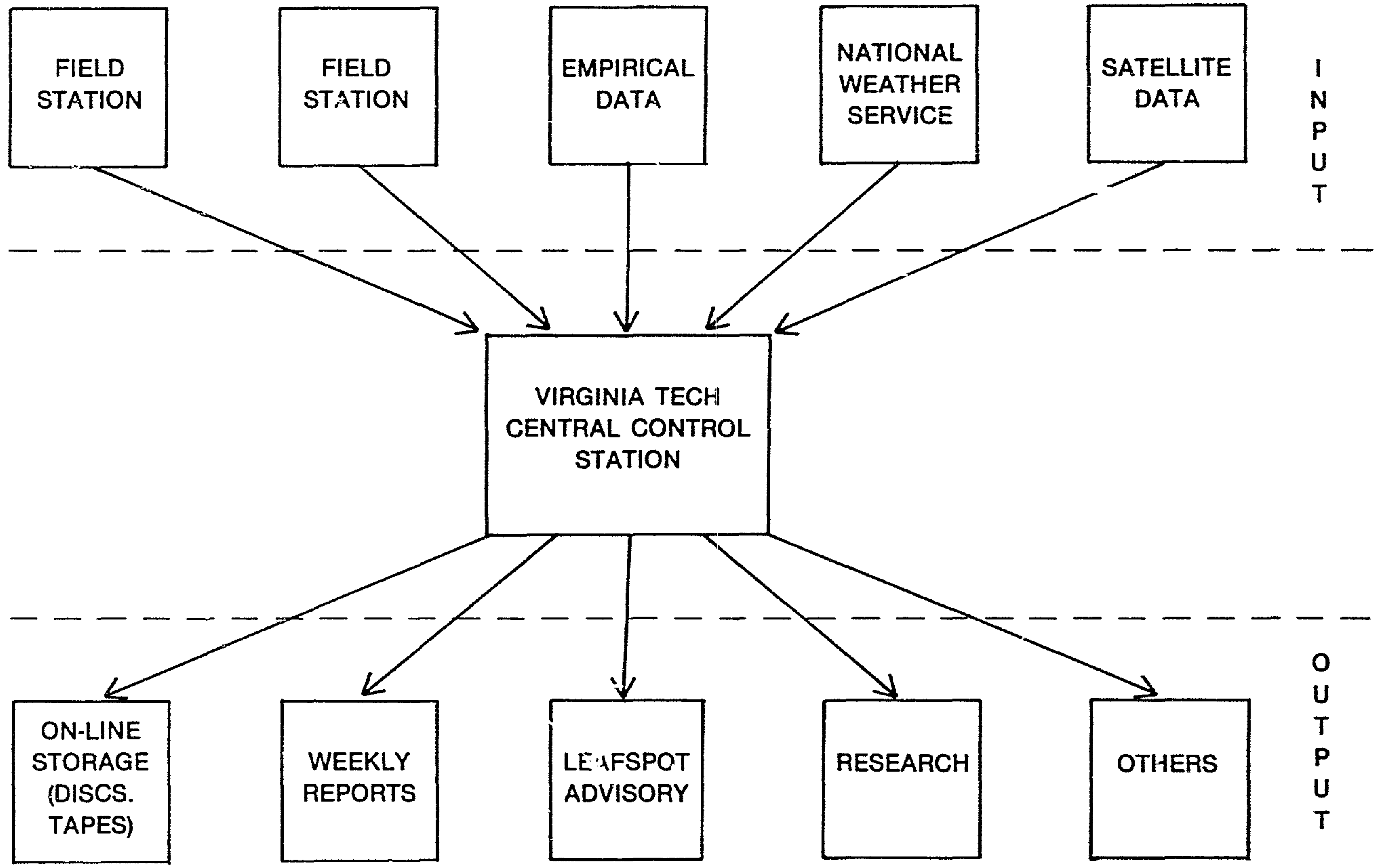

FIELD STATION
FIELD STATION
EMPIRICAL DATA
NATIONAL WEATHER SERVICE
SATELLITE DATA
INPUT
VIRGINIA TECH CENTRAL CONTROL STATION
ON-LINE STORAGE (DISCS. TAPES)
WEEKLY REPORTS
LEAFSPOT ADVISORY
RESEARCH
OTHERS
OUTPUT

Figure 5

TIDEWATER RESEARCH & CEC. SUFFOLK.   VIRGINIA

RAW DATA

DDC01 001
003500A4FBC0A5000A33C5C903380A280A4F0E51072C000E00000000023704SB00780AE1056F0000074004CF000FC00F0000C6B063AFFF6
0045003CE900BD000A3505BF033A0A2A0A500E50072C000DFFFFFFFF025804B800770AE0056FFFFE009D0066F000F000F0000C6A063AFFF6
005500BE6600BF000A3F05C90B390A2B0A4F0E51072E000D00010000020C048A00790AE205720001007A0052F000FC00F0000C6B0637FFF7
010500B71C00B7000A4805DE0B3A0A2B0A4F0E51072D000D000000002C1048A00780ADF057400C00044002DF000FC00F0000C6C063AFFF8
011500A6EA00A7000A5F05EF033C0A2D0A4E0E50072B000EFFFF00003070439007E0AE10571FFFE0027001FF00F000F0000C6B0638FFF5
012500A86800A8000A6C060703430A310A4E0E50072D000D00010001023F043A008D0AE10570FFFF001C0011F000FC00F0000C6A0637FFF6
01350098C80099000A7906030B450A340A4E0E50072D000D0000000026204BA00900AE00572FFFF0016000FF000F000F0000C6C0637FFF5
0145009C9300C9C000AB1060C0B430A350A4D0E50072D000D000000101E90459009D0AE1056C0000016000EF000F000F0000C6B0639FFF4
01550091E60092000AB2061503 4F0A380A430E50072C000D0000FFFF01D404B800A20ADF056DFFFF0012000CF000F000F0000C6C0639FFF9
0205008DDA008E000A87061403510A3C0A430E4F072C000D0000FFFF0219043A00A80AE0056AFFFF000F0006F000FC00F0000C6C063AFFF4
02150082530083000A8F060F03540A400A430E4F072C000C0000FFFF0223042900C00AE00574FFFE00090003F000F000F0000C6A0637FFF8
022500680C0068000A930616 0B590A450A430E4F072E000DFFFFFFFE028604B800C80ADF0572FFFE00050001F000FC00F0000C6E063EFFF8
023500899400B9000A9C061703 5C0A480A430E50072D000B0000FFFF026004B800E30ADF05700000FFFFFFFEF000F000F0000C6A0639FFF7
0245007CB3007D000AA9061F0B5F0A4C0A490E4D072D000DFFFFFFFF01C004B900F90ADF056EFFFEFFFDFFF9F000FC00F0000C6A0637FFF5
02550084440084000AA5062503660A4F0A490E4F072C000CFFFFFFFF01FE04B900E60AE0056A0001FFFBFFF5F000FC00F0000C6A0638FFF6
030500823800B2000AAA062803630A570A4A0E50072B000E0000FFFF020104B900EA0AE00570FFFEFFF9FFF5F000FC00F0000C6B063AFFF5
0315007 6C80077000AAA063603 6C0A5A0A490E4F072300 0B0001FFFF018704B900F30ADE0570FFFEFFFAFFF3F000F000F0000C6B063AFFF7
03250075A8C076000AAF0631036E0A5A0A470E4F072A00030000FFFF019B04B900F90ADF0572FFFEFFF7FFF4F000FC00F0000C6C0639FFF3
033500838A0083000AAC062F0B6D0A5E0A470E4F072B000CFFFFFFFF018E043800F60AE005740000FFF9FFF5F000FC00F0000C6B0639FFF5
0345007590076000A24063A03710A600A460E4F072B000B0000000000186048A00F50ADF0570FFFFFFF8FFF6F000F000F0000C6C0639FFF5
035500577E0057000A3A064903720A630A460E4D072D000DFFFFFFFE01F9048701000ADD0572FFFDFFF9FFF2F000FC00F0000C6D063AFFF4
0405006590066000AC8065203720A650A460E4D072500030000FFFF014304B801120ADE056FFFFEFFFAFFF8F000F000F0000C6D063AFFF8
04150064060064000A5F06550B770A670A460E50072D000B0001FFFE017D04B7013100ADE0573FFFFFFF7FFF7F000F000F0000C6B0639FFF4
04250049F3004A000AD6066903720A630A450E4E072A0009FFFDFFFD010B04B901480ADE0573FFFCFFF7FFF3F000F000F0000C6E0637FFF2
043500522EC052000AD3066103730A6D0A430E4E0728000 8FFFEFFFD013D04B7014F0ADD056FFFFDFFF7FFF5F000FC00F0000C6E0637FFF2
04450051030051000AF6067703770A700A460E4E072C000CFFFEFFFD01D504B7014E0ADE055EFFFDFFF7FFF6F000F000F0000C6E0639FFF2
04550041F500420003 0506E803780A750A440E4F072D000D0000FFFF042404BA01640ADE05740000FFFAFFF8F000F000F0000C6B0639FFF5
050500525C00520003 0C069C039C0A7A0A450E4F072A000CFFFEFFFE03C404B8015C0ADE056DFFFEFFFBFFF7F000F000F0000C6C0635FFF5
0515003C0D003D000031606A4037E0A780A430E4F072C00030000FFFD02B1048701820ADE056EFFFDFFFBFFF4F000FC00F0000C6C0638FFF7
0525003B86003B000031D06A7038 10A800A440E4F072C000BFFFFFFFD02CA04B8016C0ADF056DFFF0FFF6FFF8F000FC00F0000C6C063CFFF2
05350033FD0034000B02069603850A810A430E4F072P000BFFFEFFFD01A604B801AC0ADF0573FFFCFFF8FFF7F000FC00F0000C6D0633FFF7
0545003AEF003B000031806AD03840A820A450E4F072C000A0000FFFD01C204B701BF0ADF056FFFFEFFF8FFF5F000FC00F0000C6C063AFFF3
0555002BCF002C00031906BD0BE60A850A440E4E0723000CFFFEFFFF023A04B901D00ADF055EFFFDFFFCFFF7F000FC00F0000C6A0638FFF1
06050026FC00270C030E06B603900A860A430E4D0729000A0000FFFD00B604380 20A0ADE0572FFFDFFF9FFF5F000FC00F0000C6E0638FFF4
06150039DF003A000316063503920A890A400E4F0727000DFFFFFFFD07C604B702300ADD055DFFFDFFF9FFF4F000FC00F0000C6D063AFFF6
0625004956004900021D06C80B910A8C0A430E4E0723000CFFFDFFFD009F042B025D0ADE056FFFFCFFFBFFF4F000FC00F0000C6D063AFFF3
0635004DDC004E00031D06B603940A8F0A420E4E072C000AFFFDFFFD00F304B702620ADE056FFFFCFFF8FFF5F000FC00F0000C6F0639FFFA
0645003 8BC0038000356070203930A920A420E4E072D000B0000FFFD032404SB02440ADE0570FFFDFFF8FFF6F000F000F0000C6C0638FFF3
06550034010034000B61070B03970A960A440E50072B000DFFFFFFFE03CF04E802850AE0055FFFFEFFF7FFF7F000F000F0000C6C0637FFF7
07050027500280003550722 0B9A0A970A430E4F0729000AFFFFFFFE01C804280 33D0ADF0569FFFFFFF6FFF4F000FC00F0000C6B0639FFF4
071500188D001900034406E5059B0A9B0A420E4E072B000DFFFFFFFE0A70045803F20ADE0573FFFEFFF7FFF5F000FC00F0000C6A0637FFF5
0725003258003200034806FA0B9D0A9C0A420E4F072A000AFFFEFFFF00A004B704180ADD056CFFFDFFF8FFF6F000FC00F0000C6B063AFFF5
07350014260014000375073403 9F0A9E0A420E4E072B000CFFFEFFFF015404B7042F0ADF056FFFFDFFF6FFF3F000FC00F0000C6C0637FFF3
07450001DA002000B5C071C03A20AA30A430E4F0729000AFFFFFFFE01DF04B8045C0ADE0572FFFCFFF6FFF3F000FC00F0000C6E0639FFF3
07550015220015000B5D070B03A80AA60A410E4E072A0009FFFEFFFD008C0439045B0ADE056EFFFDFFF8FFF4F000F000F0000C6E0638FFF3
08050028DB0029000B58071803990AA70A420E4E072B000CFFFEFFFC02CE04B804660ADD0570FFFCFFF8FFF4F000F000F0000C6E0638FFF2
08150042C30043000B4206E50B9C0AA70A3F0E4E0728000AFFFEFFFE012004390475 0ADE055FFFFFFFF8FFF5F000FC00F0000C6E0638FFF7
0825003A6C003A00035006E4039F0AAA0A410E4E072A000CFFFDFFFE0059043A047B0ADE055DFFFFFFF9FFF5F000FC00F0000C6F063AFFF9
08350026700270C036A06F903A30AAC0A420E4E072C000BFFFDFFFC0A9804B804730ADE0573FFFDFFF9FFF3F000FC00F0000C6E063BFFF4
08450010B600100C0B5E071103A40AAE0A410E4E07290008 0000FFFE0A3A04B80470 0ADE0573FFFDFFF7FFF3F000FC00F0000C6D0639FFF3
085500092E0009000B5E07150 3A70AB00A430E4E0727000AFFFDFFFE0B9004B9048B0ADE0569FFFDFFF6FFF2F000FC00F0000C6D063AFFF2
0905002BBF00290C036B071E0BBC0AB20A420E4F072B000AFFFEFFFE093904SA04830ADE056FFFFCFFF8FFF5F000FC00F0000C6F0636FFF3
0915002F0A002F0003720723 0BAF0AB40A440E4F0729000AFFFEFFFE090E04B604860ADF056FFFFDFFF7FFF4F000F000F0000C6D0637FFF4
092500282F002B0003770723 08B20AB20A440E4D07290008FFFFFFFE096404B804800ADD056FFFFDFFF9FFF3F000FC00F0000C6D0638FFF3

Figure 6

ORIGINAL PAGE IS
OF POOR QUALITY

TIDEWATER RESEARCH & CEC. SUFFOLK. VA.

	MMDDYY	TIME	WS	PRECIP	AT	DP	ST1	ST2	ST3			WD	BP		SR	PAR			
59	10180	5	2.9	0.000	29.3	23.0	25.9	40.8	47.3	-57.6	-57.6	334.28	10.4	1.142	0.017	2.163	2.005	1.995	1.991
60	10180	15	3.4	0.000	30.2	23.7	25.8	40.6	47.1	-58.4	-58.4	337.37	10.3	1.141	0.009	6.490	2.002	1.994	1.991
61	10180	25	3.6	0.000	31.1	23.8	25.9	40.5	47.2	-58.4	-58.4	335.16	10.4	1.148	0.000	0.000	2.003	2.004	1.990
62	10180	35	3.3	0.000	30.7	24.0	26.4	40.3	47.3	-58.0	-58.0	328.18	10.4	1.150	0.000	0.000	2.004	1.998	1.998
63	10180	45	5.0	0.000	30.9	24.1	26.3	40.3	47.2	-59.6	-59.2	272.39	10.3	1.162	0.000	0.000	2.003	2.000	1.990
64	10180	55	5.5	0.000	32.4	25.2	26.1	40.2	47.1	-58.4	-58.4	353.66	10.4	1.182	0.000	0.000	2.002	1.998	1.996
65	10180	105	5.3	0.000	32.3	25.5	25.6	40.1	47.2	-58.4	-58.4	175.34	10.4	1.185	0.000	6.486	2.003	1.996	1.998
66	10180	115	5.7	0.000	32.7	26.0	25.5	40.0	47.1	-58.0	-57.6	339.58	10.4	1.187	0.000	0.000	2.002	1.994	1.994
67	10180	125	5.7	0.000	32.6	26.5	25.5	39.9	47.1	-59.2	-58.0	312.77	10.3	1.188	0.000	0.000	2.003	2.001	1.994
68	10180	135	5.3	0.000	32.5	25.7	25.5	39.9	47.1	-58.8	-58.8	78.91	10.4	1.200	0.000	0.000	2.004	1.999	1.993
69	10180	145	5.8	0.000	32.6	26.0	25.4	39.9	47.0	-58.4	-59.2	351.46	10.4	1.208	0.000	0.000	2.004	1.996	1.993
70	10180	155	6.2	0.000	33.0	26.5	25.4	39.9	47.1	-59.2	-58.4	348.61	10.4	1.223	0.003	2.164	2.003	1.999	1.991
71	10180	205	6.2	0.000	33.1	26.8	25.3	39.9	47.1	-57.6	-58.0	350.56	10.4	1.224	0.000	0.000	2.002	1.994	1.994
72	10180	215	6.4	0.000	32.8	26.4	25.0	39.7	47.0	-58.8	-58.8	22.00	10.4	1.227	0.000	0.000	2.002	1.993	1.993
73	10180	225	17.6	0.000	33.2	26.8	25.1	39.7	46.9	-58.4	-58.4	11.38	10.4	1.244	0.017	4.325	2.004	2.001	1.991
74	10180	235	5.1	0.000	33.1	26.3	25.0	39.6	47.1	-58.4	-58.4	41.25	10.4	1.252	0.009	0.000	2.005	1.999	1.989
75	10180	245	3.9	0.000	33.2	26.8	24.8	39.6	47.0	-58.0	-57.6	53.28	10.4	1.250	0.003	6.494	2.002	1.994	1.991
76	10180	255	5.1	0.000	33.3	27.3	25.2	39.6	47.0	-58.8	-58.8	17.98	10.4	1.251	0.000	0.000	2.003	2.001	1.995
77	10180	305	4.5	0.000	33.2	26.7	25.1	39.5	46.9	-58.0	-57.6	32.05	10.4	1.252	0.003	0.000	2.003	1.994	1.989
78	10180	315	4.5	0.000	33.0	26.7	25.2	39.3	46.9	-58.4	-57.6	13.19	10.4	1.250	0.000	0.000	2.002	1.994	1.993
79	10180	325	5.5	0.000	32.9	26.2	25.1	39.4	46.9	-57.6	-58.4	290.66	10.4	1.251	0.003	0.000	2.002	2.002	1.993
80	10180	335	4.7	0.000	32.7	25.7	25.1	39.3	46.8	-58.4	-58.4	345.26	10.4	1.249	0.006	8.651	2.003	1.994	1.993
81	10180	345	4.7	0.000	31.7	25.0	25.0	39.2	46.8	-58.0	-57.6	244.27	10.4	1.246	0.000	2.165	2.003	1.997	1.996
82	10180	355	5.0	0.000	31.8	25.2	25.0	39.2	46.9	-58.8	-58.4	345.64	10.4	1.252	0.000	2.166	2.003	1.999	1.993
83	10180	405	4.6	0.000	31.8	25.1	25.3	39.1	46.8	-58.0	-58.0	244.23	10.4	1.271	0.000	0.000	2.003	1.998	1.993
84	10180	415	4.3	0.000	31.8	24.8	25.1	39.1	46.7	-58.4	-58.4	21.09	10.4	1.280	0.000	0.000	2.003	1.999	1.994
85	10180	425	3.6	0.000	32.0	24.3	25.1	39.1	46.7	-57.2	-58.4	327.92	10.4	1.282	0.000	0.000	2.002	1.996	1.994
86	10180	435	3.4	0.000	30.9	24.8	25.1	39.1	46.8	-58.8	-58.8	274.88	10.3	1.281	0.000	0.000	2.003	1.995	1.991
87	10180	445	3.7	0.000	31.3	23.9	25.0	39.0	46.8	-58.8	-59.2	244.23	10.4	1.285	0.000	0.000	2.002	2.001	1.992
88	10180	455	3.8	0.000	30.9	23.8	25.1	39.0	46.8	-58.4	-58.8	56.01	10.4	1.291	0.000	0.000	2.004	1.996	1.990
89	10180	515	4.5	0.000	32.0	25.0	24.7	38.9	46.5	-58.8	-58.4	182.13	10.4	1.295	0.000	2.162	2.002	1.996	1.993
90	10180	525	4.2	0.000	31.7	24.6	24.1	38.8	46.7	-59.2	-58.8	256.31	10.4	1.288	0.000	0.000	2.002	1.998	1.993
91	10180	535	3.9	0.000	30.8	24.1	25.5	38.9	46.7	-58.4	-58.0	347.33	10.3	1.284	0.000	0.000	2.004	2.000	1.993
92	10180	545	3.2	0.000	30.9	24.1	25.5	38.8	46.6	-58.8	-58.8	349.26	10.4	1.283	0.006	4.328	2.002	2.000	1.988
93	10180	555	4.3	0.000	30.4	23.1	25.5	38.6	46.6	-58.0	-58.8	206.45	10.4	1.284	0.000	2.164	2.003	1.998	1.993
94	10180	605	4.1	0.000	30.9	23.9	25.3	38.5	46.5	-58.8	-58.0	340.71	10.4	1.293	0.000	0.000	2.003	1.996	1.994
95	10180	615	3.8	0.000	31.0	24.1	25.3	38.5	46.4	-59.2	-58.4	328.92	10.3	1.315	0.000	4.327	2.003	1.999	1.994
96	10180	625	3.9	0.000	30.8	24.2	25.2	38.5	46.5	-58.4	-58.8	280.70	10.3	1.334	0.003	0.000	2.003	1.999	1.996
97	10180	635	4.2	0.000	30.9	24.1	24.8	38.5	46.4	-59.2	-58.0	148.94	10.4	1.350	0.000	0.000	2.002	1.999	1.993
98	10180	645	4.4	0.000	31.0	24.3	24.2	38.5	46.5	-58.0	-58.0	312.82	10.4	1.371	0.000	6.492	2.004	1.999	1.992
99	10180	655	3.2	0.000	31.1	24.5	24.2	38.4	46.4	-58.0	-58.4	299.20	10.4	1.374	0.014	6.494	2.004	1.994	1.990
100	10180	705	3.3	0.000	31.6	24.7	24.3	38.4	46.3	-57.6	-58.4	325.36	10.3	1.369	0.029	8.648	2.002	1.992	1.988
101	10180	715	3.2	0.000	30.8	24.6	24.1	38.2	46.3	-57.6	-58.0	337.38	10.4	1.365	0.049	28.123	2.002	2.002	1.986
102	10180	725	3.8	0.000	31.1	26.1	24.2	38.3	46.2	-57.6	-58.4	328.45	10.3	1.371	0.094	21.626	2.002	1.994	1.993
103	10180	735	3.1	0.000	31.8	26.0	24.2	38.3	46.3	-58.0	-58.4	344.09	10.3	1.384	0.086	32.439	2.003	1.999	1.991
104	10180	745	3.8	0.000	31.8	27.2	24.2	38.3	46.2	-58.8	-58.8	331.41	10.3	1.389	0.172	41.116	2.002	1.998	1.989
105	10180	755	5.3	0.000	32.4	28.6	24.8	38.2	46.2	-58.0	-58.0	313.34	10.3	1.389	0.237	73.483	2.001	1.998	1.991
106	10180	805	5.4	0.000	33.0	30.6	24.9	38.2	46.1	-57.6	-58.4	241.25	10.4	1.352	0.295	114.655	2.003	1.999	1.990
107	10180	815	6.0	0.000	33.8	31.2	25.0	38.4	46.1	-57.2	-57.2	291.13	10.4	1.353	0.367	144.987	2.003	2.000	1.988

Figure 7

communications connection.

The software program into which these data are injected divides the state of Virginia into a grid network of 8 kilometer squares. There are approximately 3,000 of these cells required to cover the total area including some slight overlap into adjoining states to maintain a rectangular grid pattern. The square satellite data resolution elements are known as pixels (picture elements), and the exact location of each pixel is designated by values indicating longitude and latitude.

Precipitation estimates are calculated for each pixel from cloud temperature data obtained from GOES. Walton A. Follansbee, a satellite data interpretation meteorologist at Wallops Flight Center, developed the automated operation that is implemented by the computer at Virginia Tech. Each degree of temperature reported by the satellite represents an assigned amount of precipitation, and the computer converts the reading for each pixel into a precipitation value. At the end of the day hourly estimates are totaled to produce a daily precipitation estimate. This estimate is then adjusted by ground observation producing a final estimate for each pixel or grid.

There are three sources of data input to the precipitation estimation program. First, daily rain gauge readings and maximum and minimum air temperatures are collected from a network of about 150 (when fully operational) NATS volunteers. These readings are relayed to the NMC computer by the volunteers using touchtone telephone transmitters where they are readily accessible to the crop management models. Second, the National Weather Service provides 24-hour precipitation totals from about 25 weather stations in or near the state. Thirdly, the AEMS field stations supply daily precipitation inputs.

Refinement of the precipitation estimation program is under study since there are additional data sources that can be utilized. Radar data and precipitable water data from the National Weather Service are being considered. Upon completion of the 150 station volunteer network a method will be initiated that will establish interpolation factors for those areas between volunteer stations thus providing more accurate estimates for each grid cell.

D. 4. Other Data Inputs

A solar radiation estimation program is being developed utilizing satellite data from the visible portion of the electromagnetic spectrum. This data is available once each hour in digital form. Solar zenith angle and field station radiation are integrated over a 24-hour period, and a daily solar radiation estimate is made for each grid cell.

Additional data inputs are anticipated from local growers and researchers. The use of this information in crop management models will tend to provide models that are more responsive to local needs.

An AEMS Dual Pod Camera System (Figure 8) has been designed for use with the AEMS. Aerial photography is thus provided for base data input and correlation with crop conditions or growth status. The two-camera system is designed for use on a small aircraft (Cessna 182) and consists of two aerodynamically designed pods, each containing a Model 500 EL 70 mm Hasselblad camera with a magazine capacity of 100 feet. Each pod attaches to a fixed gear landing strut of the plane and contains inboard electrical connectors which attach to a single control unit that can operate each camera individually or both simultaneously.

E. THE MODELS

1. Crop Management Models in General

Early crop management models were based on plant physiology utilizing either theoretically or empirically based complex mathematical equations. These models were found to be unsuitable, and research scientists have altered them considerably. The present day versions are characterized by less complicated equations, but these equations utilize data in larger quantities that is more difficult to measure. These data may include leaf area index, light relations within vegetative canopies, stomatal resistance, CO_2, SO_2, nutrient transfer resistance, photosynthesis, respiration, and many other crop characteristics. Current models are also more specific in purpose, for example, a model is generally designed for a specific disease of a single crop. Early models attempted to treat more numerous problem situations within a single model.

There are three basic data groups necessary in all models which are utilized to simulate the plant/soil/water/atmosphere continuum:

a. Soil characteristics including hydraulic conductivity, initial soil moisture, and soil profile depth.

b. Plant properties including degree days to produce crop maturity, mature crop root distribution, days required for full crop canopy, and root extension.

c. Climatic, meteorological, and environmental data including precipitation, solar radiation, air temperature, and potential evaporation.

These data must be obtained wherever possible by automatic remote sensing, and if this is not feasible manual data collection must be initiated through the remote data terminals.

Crop management models are presently being developed to aid growers to make decisions concerning the proper management of their crops to promote increased yields and economic returns from those crops. Future research and technology may allow design of models to predict yields, however, the current state-of-the-art of the AEMS does not permit this capability. Present model developers are concentrating on pest problems, water balance in the soil, stages of plant maturity, and optimum planting dates.

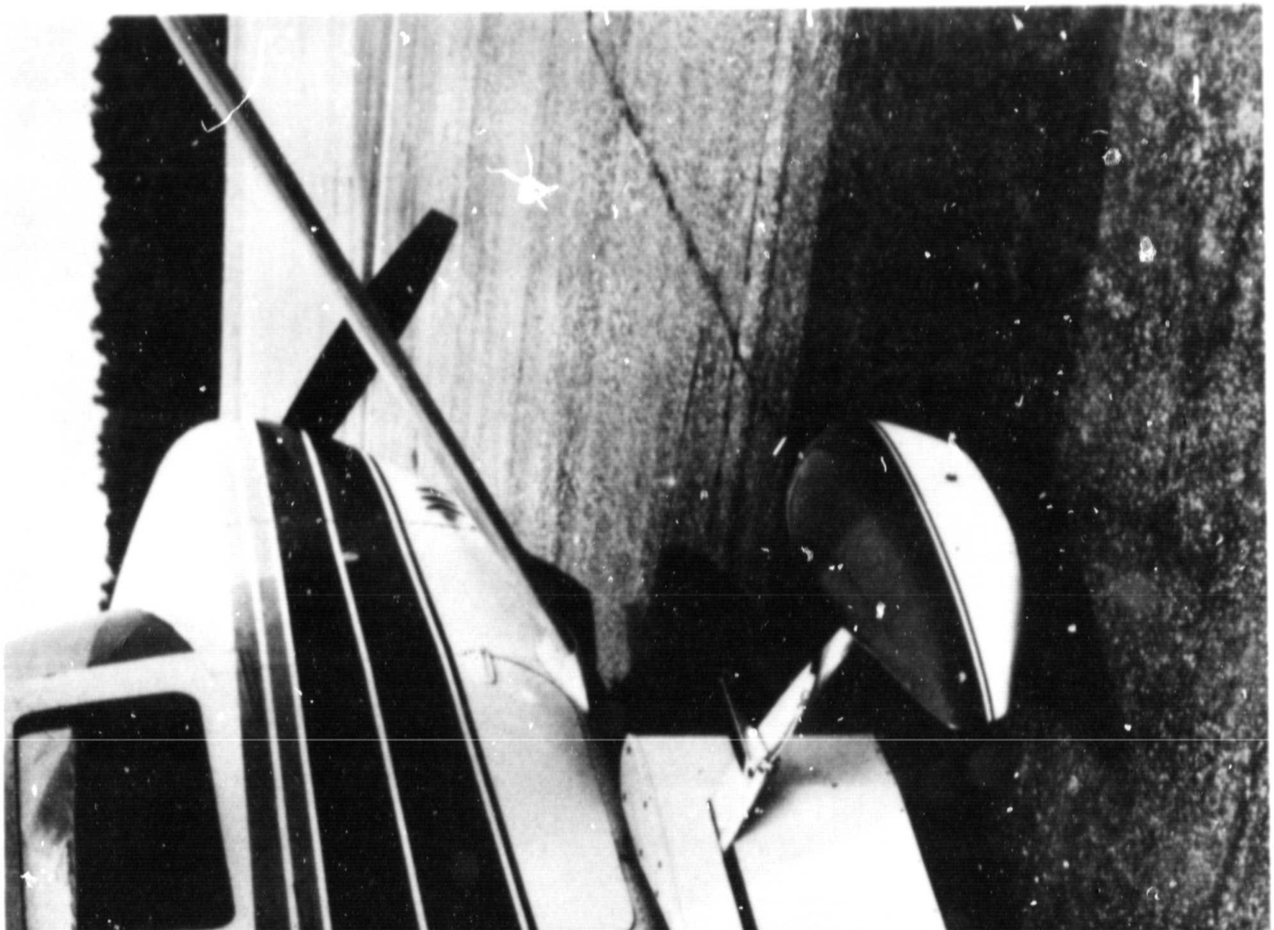


Figure 8

Many models designed for specific crop management problems may require inputs from other models to properly solve these problems. For example, an output from a water balance model may be required as an input to the crop maturity prediction model. Interaction of various models is strictly a function of design and becomes a quite useful tool when recognized by the research scientist.

The AEMS has been undergoing extensive testing and verification for the past several years. These tests have been conducted on the system using a disease of peanuts as the test problem to be modeled. Peanuts are grown on the light, sandy soils of Southeastern Virginia and Northeastern North Carolina. The crop is produced under a federal allotment program resulting in a fairly constant state production acreage of 103,000 acres.

Cercospora Leafspot is potentially one of the most serious and costly diseases that affect peanuts. At present there are no commercially grown disease resistant varieties, so the only known control is the use of fungicides in a regular spray schedule. The disease produces small brown or black spots on leaves of the infected plants. These lesions enlarge and in severe cases coalesce to form large necrotic areas that result in decreased photosynthesis. Lack of photosynthetic activity is ultimately translated into reduced yield. If the infection is severe enough the nuts separate from the vine rendering harvesting equipment useless. The disease is highly stimulated by adverse weather conditions, and the warm humid climate of Virginia enhances its proliferation. Present control consists of the initiation of a regular 14-day repetitive spray schedule when the plan begins to leaf and its continuation throughout the growing season.

The Cercospora Leafspot disease of peanuts, its characteristics, economic potential, method of control, etc., offers an excellent opportunity to test the AEMS under field conditions. Dr. Powell, the project scientist, obtained a disease model that had been developed in Georgia, modified it to adapt to Virginia's humid climate and proceeded to test the system. The Georgia studies indicated that large increases in the amount of infection were correlated with periods of high relative humidity and temperature. The basic criteria used in the model involves determination of those periods of time when the relative humidity remains above 95 percent and the temperature exceeds 70 degrees Fahrenheit.

The Cercospora model was tested on historical data during 1976 through 1978. This data was obtained from the remote monitoring stations although they were not placed into automatic operation until early 1979. 1979 and 1980 data were obtained in real time, and the model was run and updated throughout the season on a daily basis. Basically, the model simply monitors the required environmental conditions, tracking the relative humidity and temperature values. When, after looking at the previous five days, the model detects two days in which these two parameters have exceeded the predetermined threshold an alert is issued. The infection potential for each day is calculated and becomes a part of the resulting crop advisory (Figure 9). Testing was conducted under field conditions as previously described and as indicated in Figure 10.

1976 was a relatively poor year in which to foster Cercospora Leafspot disease. The model, under more humid conditions and higher temperatures, would have predicted more frequent spray applications. Therein lies one of the economic benefits of crop management modeling. During a season of high infection the model is mainly concerned with predicting when disease outbreaks may occur. However, during a season in which the disease is not as prevalent spray applications applied under model control are fewer in number than those applied under the uncontrolled 14-day schedule. The obvious benefits are twofold; (1) lower cost due to use of less time, materials, machinery, and labor, and (2) less environmental pollution due to the decreased amount of fungicide used.

Disease development (percentage of plant foliage infected) was determined at weekly intervals during the testing period, and the results are indicated in Figure 11A, 11B, 11C, and 11D. Analysis of the 1979 field tests on six farms indicated that yields were almost at the same level in those areas under control of the model as those areas sprayed at 14-day intervals (Figure 12). However, the model controlled areas were sprayed fewer times.

In 1976 there were 105,000 acres in peanut production in Virginia and 269,000 acres in adjoining areas of North Carolina. Adhering to the traditional 14-day spray schedule, Virginia farmers spent $3,465,000.00 for fungicide and it's application at least six times during the season; North Carolina farmers spent $8,877,000.00. If the Cercospora Leafspot model had been used during the 1976 season these farmers would have sprayed only three times, resulting in saving $1,762,000.00 in Virginia and $4,438,000.00 in North Carolina. The field tests during all seasons undergoing investigation have indicated fewer spray applications under model controlled conditions.

2. Pest Management Models

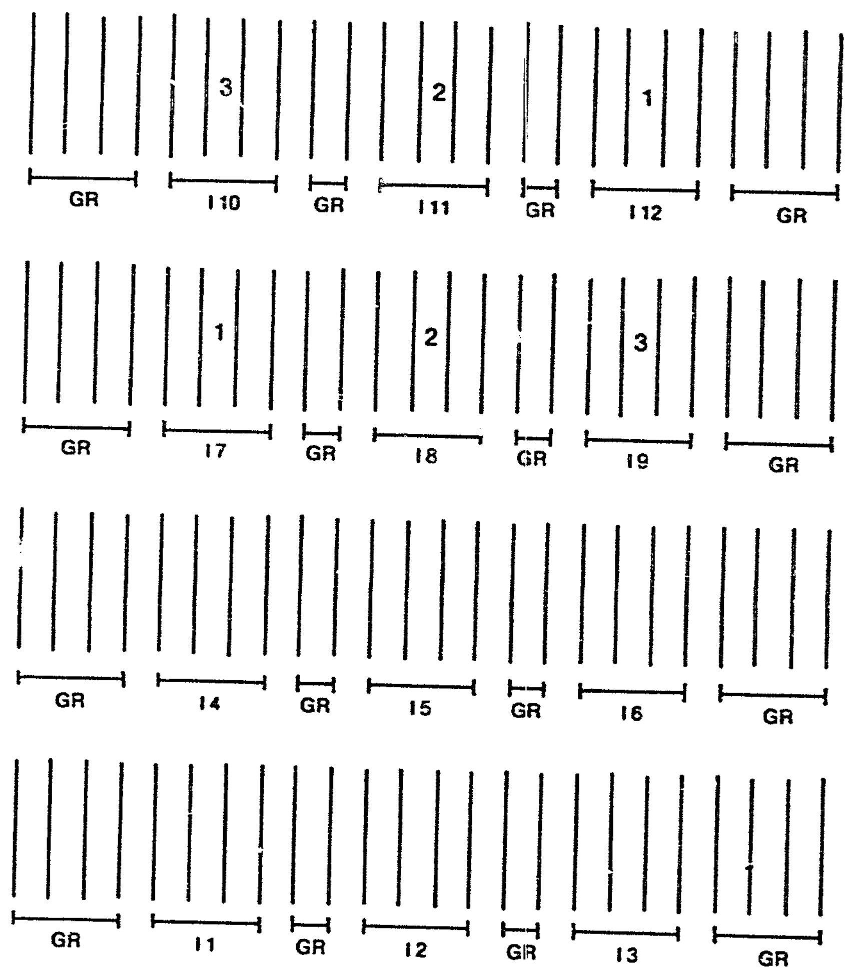
Climatic conditions are extremely important considerations of any pest/crop environment since both pests and host plants are mutually dependent on these conditions for their growth and development. Given knowledge of pest behavior and plant physiology, coupled with weather data, useful simulation activities can lead to valid pest management programs. If such programs are to be accepted by the agricultural industry they must attain a degree of realism and timeliness that will promote confidence in their results. Therefore, careful consideration must be given by the agricultural scientist to the design and development of future crop management models.

Development of two models concerned with peanut diseases is progressing satisfactorily. It is anticipated that these models, Cylindrocladium Black Rot (CBR)

```
PEANUT LEAFSPOT ADVISORY FOR VIRGINIA
****************************************
         DATE:   SEPTEMBER  1 1979
****************************************
****************************************
*****************INPUT DATA*************
*************PREVIOUS FIVE DAYS*********
             HOURS OF            LOWEST
        RELATIVE HUMIDITY     TEMPERATURE
        IN EXCESS OF 95         DURING
             PER CENT           PERIOD
                8                 71
               12                 73
               11                 71
                9                 71
               10                 73
****************************************
YESTERDAY ADVISORY CODE=5
VERY FAVORABLE
****************************************
DAILY INFECTION RATE  1.5  3.0  3.0  2.0  3.0
****************************************
*****************ADVISORY***************
****************************************
WEATHER CONDITIONS CONTINUE
VERY FAVORABLE
FOR RAPID INCREASE IN PEANUT
LEAFSPOT DISEASE DEVELOPMENT
BECAUSE OF
WARM NIGHTTIME TEMPERATURES
```

Figure 9

BUTLER (I) — CERCOSPORA TEST



1 = CHECK
2 = SPRAY, 14 DAY INTERVAL
3 = SPRAY, MODEL PREDICTED
GR = GUARD ROWS

Figure 10

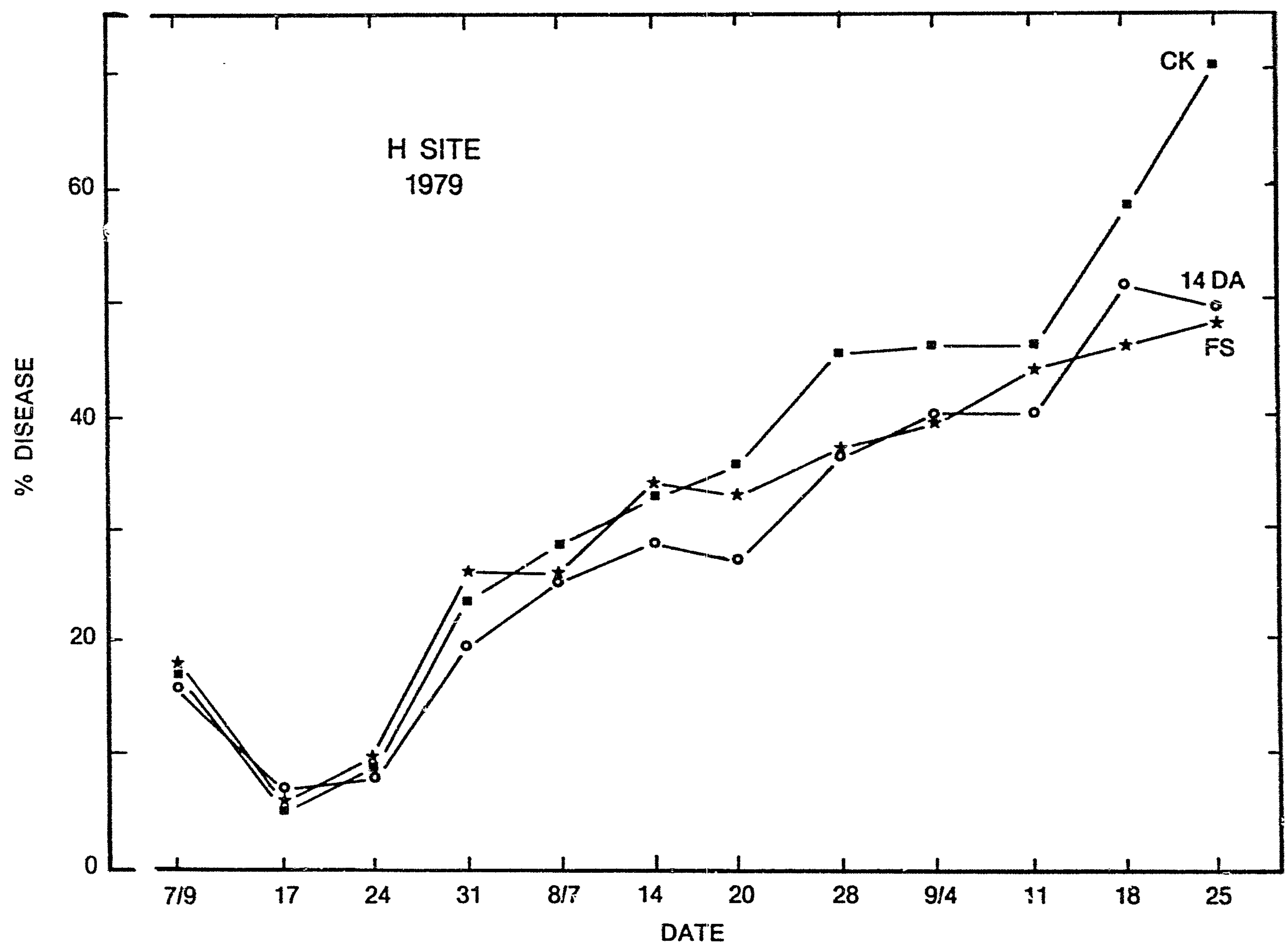

H SITE
1979
CK
14 DA
FS
% DISEASE
0
20
40
60
7/9
17
24
31
8/7
14
20
28
9/4
11
18
25
DATE

Figure 11A

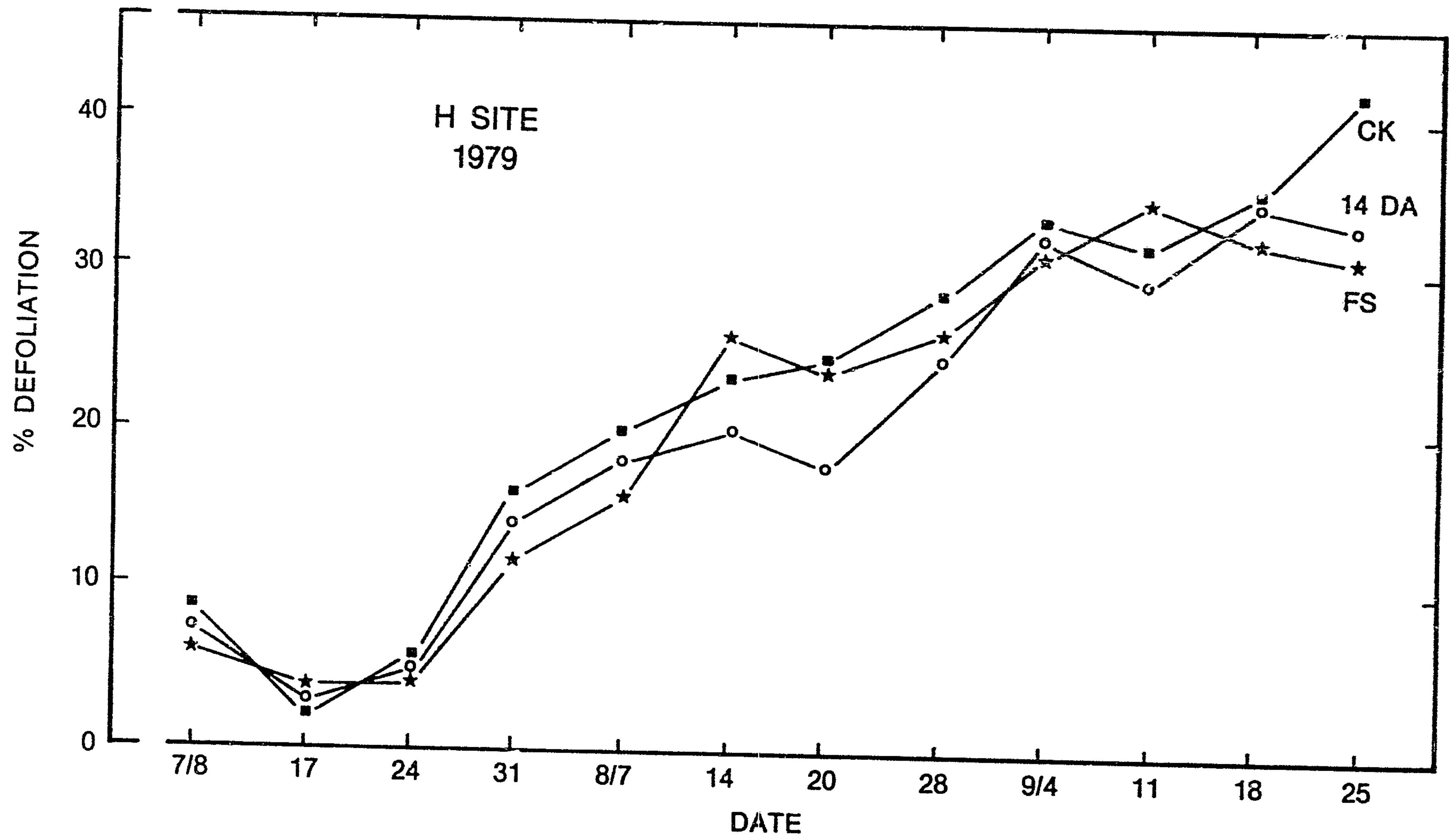

H SITE
1979
CK
14 DA
FS
% DEFOLIATION
40
30
20
10
0
7/8
17
24
31
8/7
14
20
28
9/4
11
18
25
DATE

Figure 11B

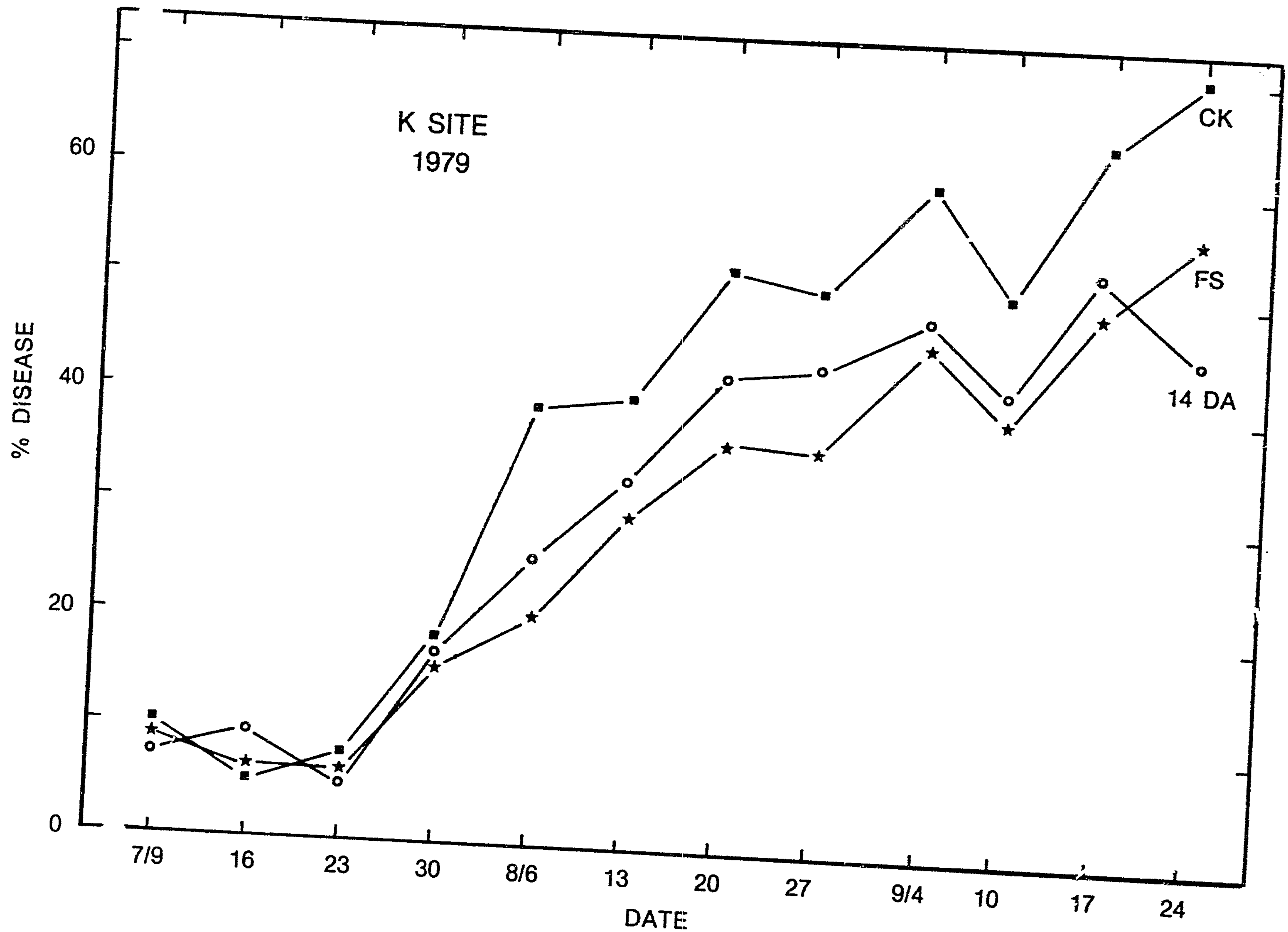

K SITE
1979
CK
FS
14 DA
% DISEASE
60
40
20
0
7/9
16
23
30
8/6
13
20
27
9/4
10
17
24
DATE

Figure 11C

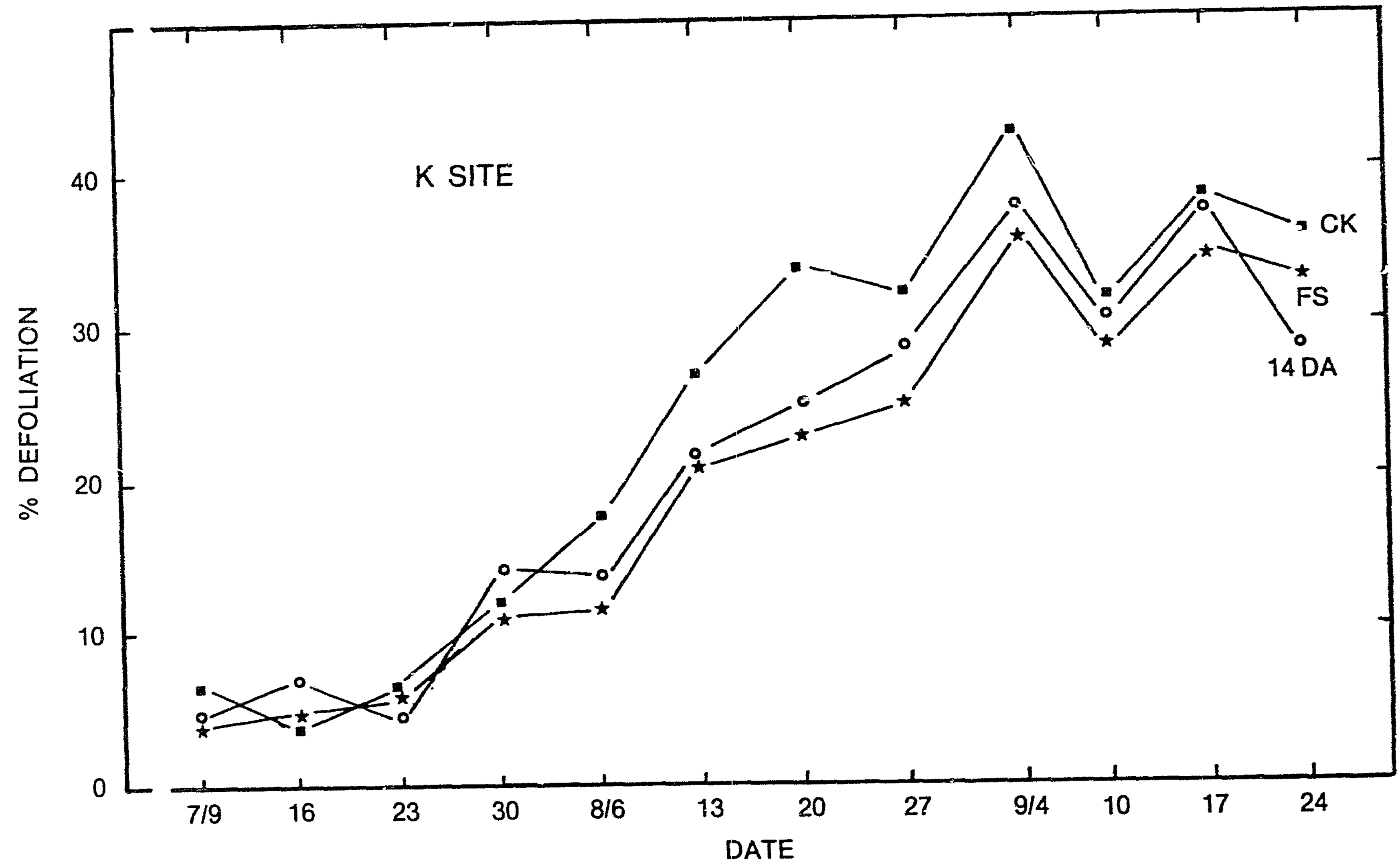

K SITE
% DEFOLIATION
0
10
20
30
40
7/9
16
23
30
8/6
13
20
27
9/4
10
17
24
DATE
CK
FS
14 DA

Figure 11D

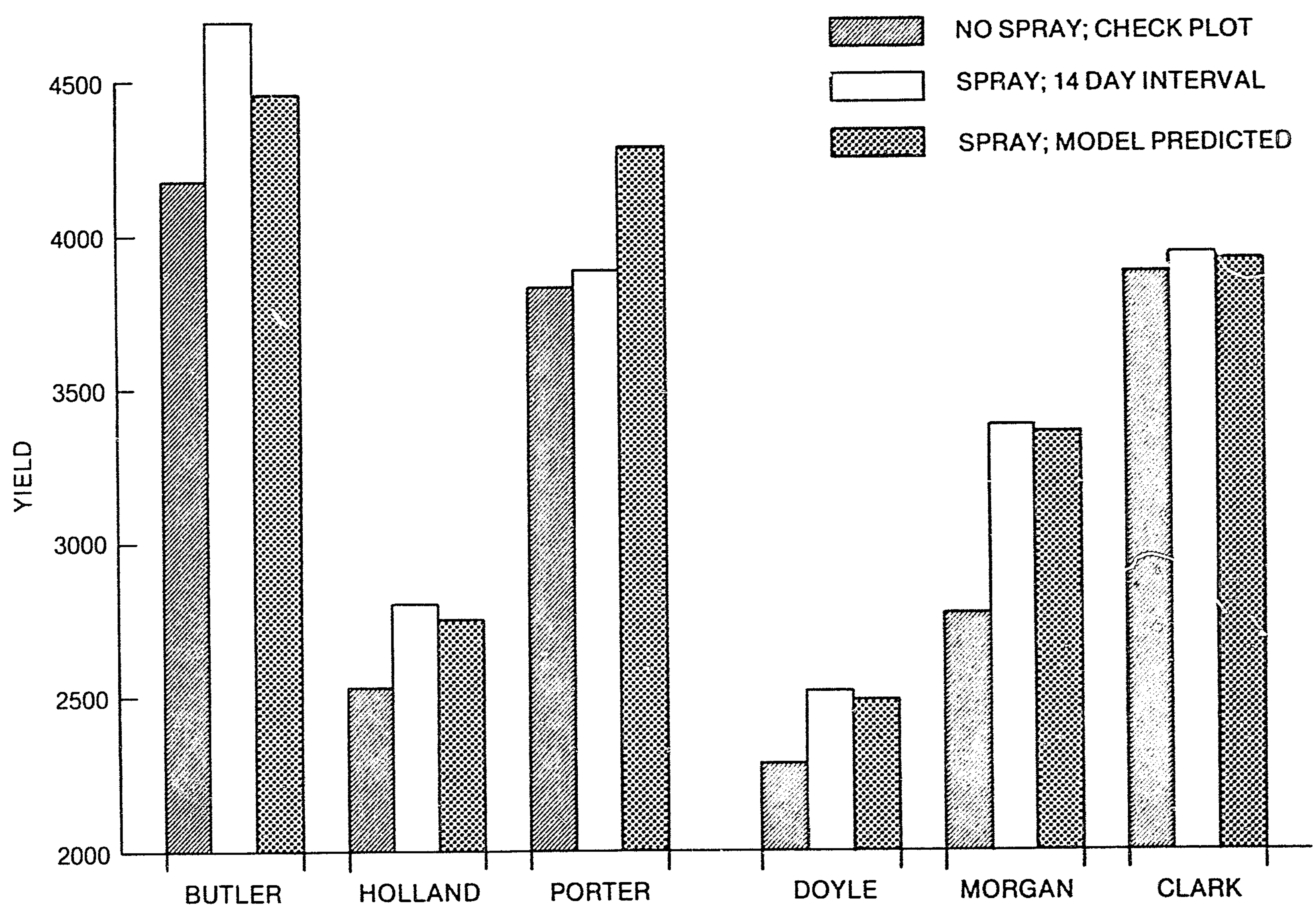


Figure 10. Cecospora Leafspot Model, 1979 Data

Figure 12

and Sclerolinia Blight will be ready for testing in the very near future. Threshold levels for each of these diseases will be determined, and the models will test hypotheses concerning optimum conditions associated with outbreaks of the diseases. Some field testing of these models took place in 1979 and 1980.

An alfalfa weevil model is also under development utilizing simulation routines that require such data as heat units (in excess of 48 degrees Fahrenheit), soil temperature, air temperature, dew point, solar radiation, etc. Threshold levels will be predicted based on the accumulation of heat units much like "growing degree days" with corn. For example, an accumulation of 200 heat units indicates the proper time to alert the farmer to a possible emergence of the alfalfa weevil.

3. Water Management Models

Irrigation, in the United States, is not necessary to produce adequate crop yields since sufficient natural precipitation is generally available. However, yields can be significantly increased by applying supplemental irrigation to maintain optimum soil moisture conditions. These humid areas produce brief but severe drought periods that may occur at critical stages in the plant's development when soil moisture stress may have a significant impact on crop yields.

It appears that plant growth is not a factor of soil moisture level alone, but rather depends on factors associated with plant stress. This stress is controlled by plant water balance, which in turn depends on relative rates of water absorption and water loss. Regardless of the water available in the soil, if flow towards the roots is less than the transpiration rate the plant suffers from water deficiency. Therefore, emphasis in the irrigation model must be placed on the maintenance of the optimum soil moisture level, but it should also indicate that point at which additional irrigation is no longer economically beneficial.

The concept of Stress Day Index (SDI) was developed to determine when supplemental irrigation is necessary. SDI represents an attempt to account for the variance in the sensitivity of crop yields to moisture deficits at different growth stages. When applied to the hydrology model the concept results in more efficient water usage which is attractive in light of energy and water shortages.

The model's determination of plant availa water is based on soil water deficits, atmospheric evaporation demand, root density and distribution, plant physiology, etc. Use of the SDI concept triggers supplemental irrigation routines whenever the daily SDI index value reaches a predetermined critical level. Prior to testing soil samples are taken to determine pH factors, nutrient levels, hydraulic conductivity, and moisture tension. During the tests soil moisture is checked twice weekly, leaf tissue is analyzed to determine nutrient level, and leaf area index and root depth are checked.

Field testing of the hydrology model has been completed for the 1980 growing season. This model requires localized data (Figure 13) upon which to make recommendations that are site specific. The main criteria, the amount of plant available water, initiated the development of a moisture retention curve. The suseptibility of crops (peanuts and corn) to moisture stress at various stages of development are matched to this curve to predict the use of supplemental irrigation. It was soon recognized that there was a period in the plant's development that was more moisture critical than others. This led to the establishment of a critical moisture retention curve that was used to maintain moisture conditions in an optimum condition. Upon completion the hydrology model should readily predict when plant stress is eminent and the amount of supplemental irrigation that is economically feasible to apply. The economic benefits of this model lie in the concept of applying water only when needed.

F. RELATED USES

The design and development of the AEMS was conceived with direct orientation to the agricultural community. However, the establishment of such a large data base of environmental information is not to be overlooked. Access to this information is available to any organization or agency through request to Virginia Tech. The data is presently being used by crop and weather reporting services. It is also being supplied for a program concerned with adaptability of individuals to thermal changes in the home as well as programs offering home heating tips. Possible use is under consideration by several state agencies that are concerned with environmentally oriented programs.

G. CONCLUSIONS

The science of crop modeling is not a new science, but previously the required computations involved with such a large data base were so numerous and cumbersome as to prove impractical for efficient use. Modern technology, particularly in the field of component miniaturization, has now advanced to the point where computational tasks that normally consumed hours can be accomplished in microseconds. The research scientist can now develop models that can be economically practical, and these models are being utilized commercially by the agricultural industry.

Development and marketing of any new commercial product presents the developer with the problem of convincing the potential user of the value and benefits of the product. Advertising compaigns are used effectively to educate the public to the desirable characteristics of the product to encourage its use. In the same manner, the AEMS and its crop management modeling program must be "sold" to the agriculturalist, and he must be encouraged to use it. The problem that must be addressed now is how the system can be

1IRRIGATED CORN: PIEDMONT RESEARCH STATION, ORANGE, VIRGINIA
THE SOIL PARAMETERS ARE---

UPPER LIMIT = 33.MM
LOWER LIMIT FOR POT. EVAP. = 8.MM
THE UPPER LIMIT FOR STAGE I SOIL EVAPORATION IS 6.0
THE STAGE II SOIL EVAPORATION EQUATION IS--
SUMES = 4.0T**0.5

ELEVATION = 510.
SOIL ALBEDO = 0.15

SEGMENT NO. 1
PLANT POPULATION = 28000.PLANT/ACRE
ROW SPACING = 30.INCHES

LEAF AREA INDEX FOR SEGMENT 1

DAY	LAI
1	0.0
30	0.0
35	0.09
40	0.22
45	0.45
50	0.89
60	2.23
70	4.02
75	4.91
85	4.91
105	4.91
115	4.91
125	4.91
150	4.91

MULCH RATE FOR SEGMENT 1

DAY	KG/HA
1	0.0
365	0.0

1IRRIGATED CORN: PIEDMONT RESEARCH STATION, ORANGE, VIRGINIA

MO	DAY	YR	JDAY	NET RAD. (MM/DAY)	LEAF AREA INDEX	TRAN RAD.	MULCH RATE (KG/HA)	RAIN (MM)	INTCEP (MM)	RUNOFF (MM)	DRAINAGE (MM)	POT. EVAP. (MM/DAY)	PLANT EVAP. (MM/DAY)	SOIL EVAP. (MM/DAY)	INTCEP EVAP. (MM/DAY)	TOTAL EVAP. (MM/DAY)	SOIL WATER (MM)	PAW (%)	IRR LEV (%)
4	23	80	1	4.2	0.0	1.00	0.	0.0	0.0	0.0	0.0	3.5	0.0	3.51	0.0	3.51	28.	86.	0.
4	24	80	2	4.2	0.0	1.00	0.	2.03	0.0	0.0	0.0	3.6	0.0	3.58	0.0	3.58	27.	82.	0.
4	25	80	3	4.2	0.0	1.00	0.	0.51	0.0	0.0	0.0	3.5	0.0	2.69	0.0	2.69	25.	75.	0.
4	26	80	4	1.0	0.0	1.00	0.	5.33	0.0	0.0	0.0	0.7	0.0	0.73	0.0	0.73	29.	89.	0.
4	27	80	5	1.5	0.0	1.00	0.	9.40	0.0	0.0	0.0	1.1	0.0	1.08	0.0	1.08	33.	100.	0.
4	28	80	6	2.9	0.0	1.00	0.	0.0	0.0	0.0	0.0	2.1	0.0	2.13	0.0	2.13	31.	94.	0.
4	29	80	7	4.3	0.0	1.00	0.	3.56	0.0	0.0	0.0	3.3	0.0	3.25	0.0	3.25	31.	94.	0.
4	30	80	8	4.3	0.0	1.00	0.	0.76	0.0	0.0	0.0	3.3	0.0	3.35	0.0	3.35	29.	87.	0.
5	1	80	9	4.3	0.0	1.00	0.	0.0	0.0	0.0	0.0	3.5	0.0	2.15	0.0	2.15	26.	80.	0.
5	2	80	10	4.3	0.0	1.00	0.	0.0	0.0	0.0	0.0	3.6	0.0	2.48	0.0	2.48	24.	73.	0.
5	3	80	11	4.3	0.0	1.00	0.	0.0	0.0	0.0	0.0	3.5	0.0	1.53	0.0	1.53	22.	68.	0.
5	4	80	12	4.4	0.0	1.00	0.	0.0	0.0	0.0	0.0	3.8	0.0	1.21	0.0	1.21	21.	64.	0.
5	5	80	13	4.4	0.0	1.00	0.	0.0	0.0	0.0	0.0	3.9	0.0	1.04	0.0	1.04	20.	61.	0.

Figure 13

"advertised" to convince the public of its value. Virginia Tech is presently attempting to solve this problem by conducting a study analysis of the system and its potential for acceptance. A detailed report of this investigation is pending.

Development of the system, subject to physical and economic considerations, is being developed within and for the state of Virginia. As an operating system, it is easily expandable to neighboring states or even much larger areas. Such expansion will depend heavily on the performance and proven benefits of the present system. The expansion potential from within the system is almost unlimited. Many models of many pests of a large number of crops are possible under the scope of the AEMS. Therefore, the future lies in the hands of those research scientists willing to obtain or design crop management models and teach the user to utilize them.